ISSN: 2720-989X
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JOURNAL OF ENERGY AND ELECTRICAL ENGINEERING

Electricity Demand Forecasting in NTT Province For 2024-2034 Using Software Low Emissions Analysis Platform (LEAP)

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[*submitted*: 20-08-2024 | *review*: 24-10-2024 | *published*: 31-10-2024]

ABSTRACT: *This study aims to electricity demand forecasting and optimize New Renewable Energy (NRE) to supply electrical energy demand in East Nusa Tenggara (NTT) Province 2024-2034 using Low Emissions Analysis Platform (LEAP) Software, considering factors of population growth, economic growth, and government policies related utilization NRE and environment. The method used is a quantitative descriptive end-use model. High, medium, and low scenarios were added to make the research results more adaptive. Moreover, PLTD and PLTU are scenarios that will experience decreased installed capacity until 2034. The results of forecast electricity demand 2024-2034 in NTT Province, for the high scenario increased from 1,448.49 GWh to 2,018.56 GWh with average growth of 3.50%, medium scenario increased from 1,318.91 GWh to 1,595.31 GWh with average growth of 2.06%, low scenario increased from 1,200.10 GWh to 1,359.33 GWh with average growth of 1.39%. Optimization of NRE in the high, medium, and low scenarios shows that NRE can supply electricity demand until 2034*

KEYWORDS: *Electricity Demand Forecasting, LEAP, NTT Province, Optimization NRE.*

I. INTRODUCTION

Electrical energy is one of the energies that is needed by society, for example for lighting, air conditioning, television, and refrigerators [1]. This causes dependence on electrical energy to continue to increase occasionally.

This dependence is one of the impacts of technological progress, population growth, and economic growth so the need for electrical energy increases[2][3].

The current trend is that the increase in the need for electrical energy is not in line with the increase in the supply of electrical energy, where the installed power capacity remains the same while the public's need for electrical energy continues to increase, and vice versa[4][5]. In addition, operating power plants are still dominated by fossil energy plants whose energy sources will one day run out. Therefore, the reliability of the electrical energy supply is very important [6].

East Nusa Tenggara (NTT) is a province in Indonesia that is known as Flobamorata, which is a collection of five large islands in NTT (Flores, Sumba, Timor, Alor, and Lembata). The land area of NTT is 46,452.38 km2 with the island of Timor as the largest island (14,088.71 km2). The administrative area in NTT in 2021 is divided into 21 districts and 1 city. The largest areas are East Sumba Regency with an area of 6,985.33 km2 (15.04%) and Kupang Regency with an area of 5,143.36 km2 (11.07%). The smallest area is Kupang City with an area of 152.59 km2 (0.33%). Because it is an island province, access to the capital of NTT province, Kupang, is achieved by several means. Land routes/land transportation are used for regencies/cities on the island of Timor (Kupang Regency, South Central Timor, North Central Timor, Belu, Malaka, and Kupang City).

For other districts, you can use sea and/or air routes. Regions in NTT have varying temperatures. Of the 10 meteorological and climatological stations in NTT, the highest recorded temperature in 2023 was 32.8°C and the lowest was 15.8°C. In general, the NTT area is classified as hot with an average temperature of between 27–28°C[7].

To meet the electrical energy needs in NTT and also to minimize the consequences that will occur in the coming year, it is necessary to carry out an accurate forecast of electrical energy needs, both from technical and economic factors [8][9]. If the forecast of electrical energy needs is inaccurate, the consequence is that people will not get enough electrical energy. On the other hand, forecasting electrical energy requirements that are too high can cause excess energy capacity, which in the end can cause losses [10].

Apart from forecasting electrical energy needs, it is also necessary to optimize New Renewable Energy (NRE). One way is to carry out energy transformation. Energy transformation helps optimize energy use and increase the efficiency of the energy system as a whole as well as to reduce dependence on certain energy sources, in this case, fossil energy sources [11].

Based on the problems above, it is necessary to forecast electrical energy needs and optimize NRE in

NTT Province in 2024-2034. This was triggered by population growth and economic growth in NTT Province in the last five years which tended to increase as well as government policies regarding the use of NRE and the environment.

This is also in line with the Indonesian government's commitment to increase the use of new renewable energy (NRE) as stated in Law number 30 of 2007 concerning energy, Presidential Regulation number 112 of 2022 concerning the acceleration of the development of new renewable energy for the supply of electricity, then Government Regulations number 79 of 2014 concerning National Energy Policy (KEN), and Government Regulation number 22 of 2017 concerning the General National Energy Plan (RUEN).

To make this research process easier, software can be used. One software that can be used is the Low Emissions Analysis Platform (LEAP). LEAP was chosen because it can be used to analyze and evaluate energy policies and planning, has an interface that is easy to understand, and is easy to use because it requires little data [12][13].

II. METHODOLOGY

The method used to forecast electrical energy needs and optimize NRE in NTT Province in 2024-2034 is a descriptive method with a quantitative approach. This method is used because it can explain the situation to be researched with the support of a literature study so that it further strengthens the researcher's analysis in collecting, processing, and obtaining research results so that the conclusions obtained will be more accurate.

For the simulation process, LEAP software uses an end-use modeling approach, namely considering the end use of energy. The data used in this research is secondary data for the last five years (2018-2022) from several agencies or companies in the form of population, number of household members, Gross Regional Domestic Product (GRDP), electrical energy consumption and customers per sector, (capacity installed, capacity and electrical energy production) per power plant, peak load and energy losses, electrification ratio, power plant construction plans and planning reserve margin as stated in the 2021-2030 Electricity Supply Business Plan (RUPTL). The steps for this research can be seen in Fig 1 below.

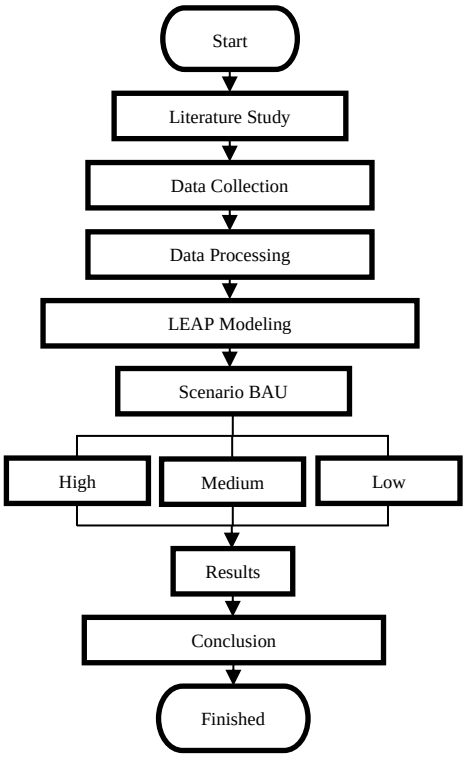


Fig 1. Research Flow Diagram

III. RESULTS AND DISCUSSION

This section is the most important part of an article's content. In this section there is an answer to a research objective. Apart from being in paragraph form, this section usually contains a lot of supporting data in the form of pictures, Tbls, graphs, etc.

A. DATA COLLECTION

Data for the last five years (2018-2022) collected from several agencies or companies is as follows.

1) *Total Population and Household Members*

Tbl 1. Total Population and Number of Household Members

Year	Total Population	Growth (%)	Household Members (People)
2018	5.371.520	-	4,62
2019	5.456.200	1,58	4,62
2020	5.325.570	-2,40	4,82
2021	5.387.740	1,17	4,62
2022	5.466.290	1,46	4,62
Average	***5.401.464***	***0,45***	***4,66***

From Tbl 1, it is known that the average population in 2018-2022 was 5,401,464 people and the average population growth in 2018-2022 in NTT Province per year was 0.45% with the largest growth occurring in 2019 with a growth of 1.58% and the smallest occurred in 2020 where there was negative

growth of -2.40%. This was influenced by the pandemic disaster that occurred (Covid-19). Meanwhile, the average number of household residents per year is 4.66 people per household.

2) GRDP Constant Price 2010 According to Business Field

Based on GRDP data based on constant prices according to business fields in NTT Province which have been obtained and processed, the results shown in Tbl 2 below will be obtained.

Tbl 2. GRDP Constant Price 2010 According to Business Field

GRDP Constant Price 2010 (Million Rupiah)								
Year	***Total***	***Growth (%)***	***Business***	***Growth (%)***	***General***	***Growth (%)***	***Industrial***	***Growth (%)***
2018	65.929.193,54	-	22.022.561,25	-	24.224.432,1	-	1.844.393,84	-
2019	69.389.016,38	5,25	23.182.839,02	5,27	25.757.049,47	6,33	1.953.121,85	5,90
2020	68.809.614,28	-0,84	22.958.635,3	-0,97	25.382.874,7	-1,45	1.787.463,85	-8,48
2021	70.540.556,64	2,52	23.689.851,5	3,18	25.481.831,6	0,39	1.766.975,69	-1,15
2022	72.695.277,01	3,06	24.905.756,9	5,13	25.603.601,4	0,48	1.844.186,37	4,37
Average	***69.472.731,6***	***2,50***	***23.351.928,8***	***3,15***	***25.289.957,8***	***1,44***	***1.839.228,32***	***0,16***

Based on Tbl 2 above, the total GDP, business, and general sectors in 2020 experienced negative growth and only in the following year experienced positive growth. Meanwhile, the industrial sector experienced negative growth in 2020 and 2021 and only experienced positive growth in the following year. The negative growth that occurred was the result of the pandemic disaster that occurred (Covid-19).

3) Electrical Energy Consumption and Customer by Sector

Tbl 3. Electrical Energy Consumption and Customer

No	Sector	Year				
		2018	**2019**	**2020**	**2021**	**2022**
1	**Energy Consumption (GWh)**					
	Household	546,92	596,52	729,29	749,03	759,36
	Business	231,54	237,44	232,18	238,66	270,56
	General	108,98	117,18	124,04	131,28	148,67
	Industrial	39,97	48,35	47,97	41,19	28,31
	Customer					
2	Household	658.439	758.498	867.622	954.074	1.036.252
	Business	32.479	32.421	33.352	34.318	35.715
	General	22.571	25.308	27.875	29.819	31.867
	Industrial	207	216	239	276	336

From Tbl 3 above, it is known that electrical energy consumption for the household and general sectors will continue to increase until 2022. Meanwhile, the business sector experienced a decrease in consumption in 2020 and increased again in the following year until 2022, and for the industrial sector, there was a decrease in consumption. until 2022. Meanwhile, customers for the household, general and industrial sectors continued to increase until 2022, for the business sector customers experienced a decline in 2019 and began to increase again in the following year until 2022[14]. For the public sector, both electrical energy consumption and customers are a combination of the social sector, government buildings, and public street lighting.

4) Installed Capacity Per Power Plant

Tbl 4. Electrical Energy Consumption and Customer

Installed Capacity Power Plant (MW)					
Year	**2018**	**2019**	**2020**	**2021**	**2022**
PLTU	47	47	47	47	47
PLTMG	-	71,45	119,44	119,44	119,44
PLTD	194,29	166,92	165,03	168,07	172,59
PLTA	5,28	5,28	5,28	2,32	2,32
PLTMH	-	-	-	2,96	2,96
PLTB	0,09	0,09	0,09	0,09	0,09
PLTP	12,50	12,50	12,50	12,50	12,50
PLTS	1,06	1,06	3,98	7,07	8,87
SEWA	73,50	59	48	104,50	87
IPP	97,03	101,03	101,03	41,03	46,03
Total	430,75	464,33	502,35	504,98	498,8

From Tbl 4 it can be seen that the electricity generation in NTT Province does not only come from State Electricity Company (PLN) owned plants but also from tenants and Independent Power Producers (IPP). The generator provided by the lessee is a PLTD-type generator, while the generator from the IPP is not defined due to data limitations. From the data above, it

can also be seen that the total installed capacity of power plants from 2018 to 2021 continues to increase, and then in 2022, it decreases.

5) Capable Power Per Power Plant

Tbl 5. Cable Power Per Power Plant

Power Generation Capability (MW)					
Year	**2018**	**2019**	**2020**	**2021**	**2022**
PLTU	25,48	36,51	39	42	44
PLTMG	-	62,66	102,66	102,66	110,90
PLTD	88,88	58,20	56,76	60,02	84,43
PLTA	4,65	4,62	4,17	1,75	2,29
PLTMH	-	-	-	2,08	2,61
PLTB	-	-	-	-	-
PLTP	9	9,90	9,90	9,05	9,76
PLTS	0,71	0,71	3,06	4,61	7,46
SEWA	75,25	31,85	43,12	104,50	87
IPP	94,40	99,10	68,27	37,80	46,03
Total	298,37	303,55	326,94	364,47	394,48

From Tbl 5 above, it can be seen that the total power generation capability in NTT Province in 2018-2022 continues to increase. In 2022, the generator with the largest capacity is PLTMG with 110.90 MW and the smallest is PLTA with 2.29 MW.

6) Electrical Energy Production

Tbl 6. Electrical Energy Production Per Power Plant

Power Generation Capability (MW)					
Year	**2018**	**2019**	**2020**	**2021**	**2022**
PLTU	139,99	238,32	283,95	302,56	357,51
PLTMG	-	103,06	234,85	310,03	311,65
PLTD	87,10	73,55	67,78	66	59,92
PLTA	10,95	11,60	13,21	7,67	11,44
PLTMH	-	-	-	5,38	5,49
PLTB	-	-	-	-	-
PLTP	44,26	53,13	57,25	56,44	55,37
PLTS	0,52	0,77	1,84	2,42	3,24
SEWA	348,53	277,02	246,99	435,39	385,63
IPP	404,99	378,16	336,63	125,65	223,19
Total	1.036,34	1.135,61	1.242,5	1.311,54	1.413,44

From Tbl 6 it can be seen that total electrical energy production from 2018-2022 continues to increase. This increase in production is in line with electrical energy consumption in 2018-2022 which continues to increase. The generator with the largest electrical energy production in 2022 is SEWA which uses fossil fuels at 385.63 GWh and the smallest is PLTS at 3.24 GWh.

7) Peak Load and Energy Losses

Tbl 7. Peak Load and Energy Losses

Year	Peak Load (MW)	Energy Losses (%)
2018	250,91	8,35
2019	226,57	9,13
2020	142,40	5,79
2021	337,93	8,23
2022	311,40	12,08

Based on the data in Tbl 7, the peak load for the last five years has experienced ups and downs with the largest peak load occurring in 2021 and the smallest in 2020. The decrease in peak load in 2020 was caused by the pandemic (Covid-19) which caused economic activity to decrease. slow and there are restrictions on community mobility. Meanwhile, the highest energy losses occurred in 2022 at 12.08% and the smallest in 2020 at 5.79%.

8) Power Plant Construction

Based on RUPTL 2021-2030 data, it is hoped that in 2024 the national electrification ratio target will be 100%, then in 2025 the minimum new renewable energy (NRE) mix will be 23%, petroleum less than 25%, coal at least 30%, and gas at least 22%. To support the above targets, several power plants will be built in NTT Province, both from PLN and IPP with a total capacity of 356 MW[15]. The details can be seen in Tbl 8 below:

Tbl 8. Power Plant Construction Plan

Year	2024	2025	2026	2027	2028	2029	2030	Total
PLN and Non PLN (MW)								
PLTU	-	12	-	24	-	-	-	36
PLTMG	30	-	-	-	-	-	-	30
PLTP	16	41	15	20	10	5	-	107
PLTS	15	5	10	-	11	-	10	51
PLT EBT	-	-	50	-	50	-	-	100
PLTM	-	10	-	-	-	-	-	10
PLTB	22	-	-	-	-	-	-	22
Total	83	68	75	44	71	5	10	356

9) Electrification Ratio (ER)

Tbl 9. Electrification Ratio

Year	ER (%)	Growth ER (%)
2018	61,9	-
2019	85,8	2,07

2020	87,6	38,6
2021	89	1,59
2022	92,7	4,15
Average		11,62

From Tbl 9, the average annual growth in the electrification ratio is 11.62%, with the largest growth occurring in 2019 at 38.68% and the smallest occurring in 2021 at 1.59%.

B. ANALYSIS AND DISCUSSION

Based on the data that has been collected and the explanation of the research method, to analyze the results of forecasting electrical energy needs and optimizing NRE in NTT Province using LEAP software.

1) *Electrification Ratio (ER)*

In this study, the variables entered into the LEAP software are population, total GRDP per customer sector, electrification ratio, energy intensity per customer sector, number of household occupants, peak load ratio, reserve margin, transmission and distribution losses, electricity generation in NTT Province, power generation capacity and electrical energy production.

To estimate electrical energy needs, the data assumptions used are population growth, economic growth per customer sector, electrification ratio, energy intensity per customer sector, and number of household occupants.

Meanwhile, to optimize NRE, the assumed data used is government policy based on the 2021-2030 RUPTL in the form of planning reserve margin and power plant development plans in NTT Province which are in Tbl 8. Then the Loss values (transmission, distribution, and own use), and Maximum Availability of power plants in NTT Province.

2) *Electrification Ratio (ER)*

After the assumed values are obtained, the variable data is then entered into the Current Account scenario or basic values in LEAP. The basic value scenario itself is data from the latest year, namely 2022.

In this research, the scenarios used are high, medium, and low scenarios. The use of these three scenarios is intended so that the results obtained will be more adaptive. Apart from being adaptive, using these three scenarios is also useful for dealing with uncertainty, making better decisions, increasing system resilience, and encouraging innovation.

To estimate electrical energy needs, the high scenario uses assumed growth percentages (population and economy) and the highest energy intensity values. Then for the medium scenario, use the assumed growth percentage (population and economy) and moderate energy intensity values, and for the low scenario, use the assumed growth percentage (population and economy) and the lowest energy intensity value. Based on information obtained from press releases from pln.co.id media, the electrification ratio in NTT Province is targeted to reach 100% by 2025.

Meanwhile, to simplify the simulation process, the number of household residents with an average value of 4.66 people per household was rounded up to 5 people per household. For more details, see Tbl 10 below.

Tbl 10. Assumption for Electricity Demand Forecasting

Description	Assumption		
	High	*Medium*	*Low*
Population Growth	1,58%	1,17%	0,45%
Business GRDP Growth	5,27%	3,19%	3,16%
General GRDP Growth	6,33%	1,44%	0,39%
Industrial GRDP Growth	5,90%	4,37%	0,16%
Household Energy Intensity	0,00084056	0,00079510	0,000732779
Business Energy Intensity	0,00001086	0,00001036	0,00001007
General Energy Intensity	0,00000581	0,00000498	0,00000450
Industrial Energy Intensity	0,00002684	0,00002239	0,00001535

To optimize NRE, the same assumed values are used for the three scenarios. For planning reserve margin, use the standards in the 2021-2030 RUPTL. The planning for additional power plants is adjusted to the data in Tbl 8 by optimizing the NRE generator first. Then the Maximum Availability value for the new power plant is adjusted to the power plant that is already operating. All of these generators are regulated in the form of dispatch (Dispatch Rule) which is adjusted to the order (Merit Order). Merit Orders 1, 2, and 3 state orders for low, medium, and high loads.

In this research, generators that use new renewable energy sources and coal are set to meet low loads because their operating costs are lower.

Meanwhile, PLTMG, SEWA, and IPP are to meet medium loads and PLTD is regulated to meet high loads because of their higher operating costs. For more details, the assumptions for optimizing NRE can be seen in Tbl 11 below.

Tbl 11. Assumption for NRE Optimization

Description	Assumptions (%)
Planning Reserve Margin	35
Losses	8,72
Maximum Availability	
PLTU	79,57
PLTMG	88,11
PLTD	39,93
PLTA	85,74
PLTMH	79,22
PLTM	79,22
PLTB	80
PLTP	76,18
PLTS	72,03
PLT EBT	80
SEWA	89,24
IPP	91,02

3) Forecast Result

A) Total Population

From the simulation process, the results showed that the population of NTT Province continues to increase, where for the high scenario the population in 2024 will be 5,639,997 people and at the end of 2034 it will reach 6,594,922 people. For the medium scenario, the population in 2024 will be 5,594,660 people and at the end of 2034, it will reach 6,283,174 people. Meanwhile, for the low scenario, the population in 2024 will be 5,515,807 people and at the end of 2034, it will reach 5,770,201 people. For more details, see Fig 2 below.

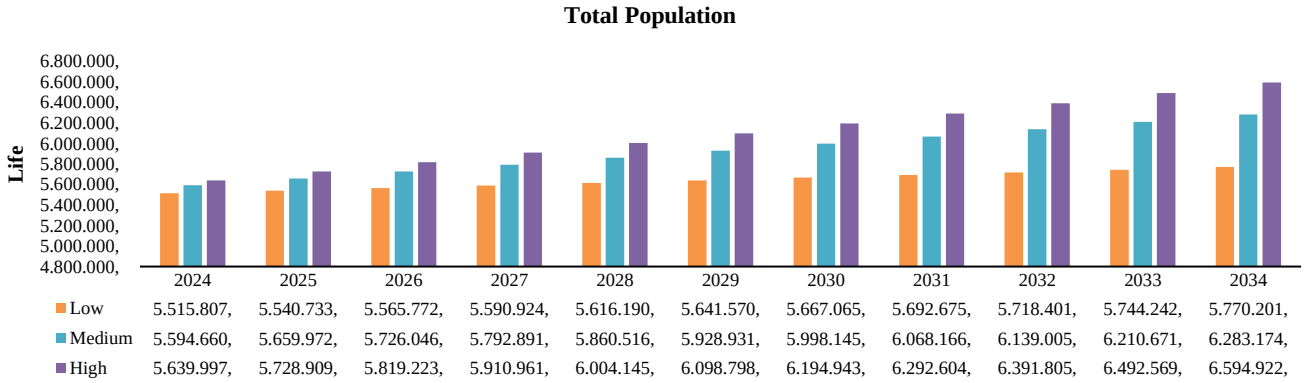


Fig 2. Population Forecast for High, Medium and Low Scenarios for 2024-2025

B) Number of Household Customer

From the simulation results, it was found that the number of household customers for the high scenario in 2024 was 1,100,551 customers and increased to 1,318,984 customers at the end of 2034 with an average customer growth of 2.04%. During that year, household customers increased by 218,433 customers. For the medium scenario, household customers in 2024 will number 1,091,705 customers and will increase to 1,256,635 customers at the end of 2034 with an average customer growth of 1.63%. During that year, household customers increased by 164,930 customers. Meanwhile, for the low scenario, household customers in 2024 will number 1,076,318 customers and will increase to 1,154,040 customers at the end of 2034 with an average customer growth of 0.91%. During that year, household customers increased by 77,722 customers. For more details, see Fig 3 below.

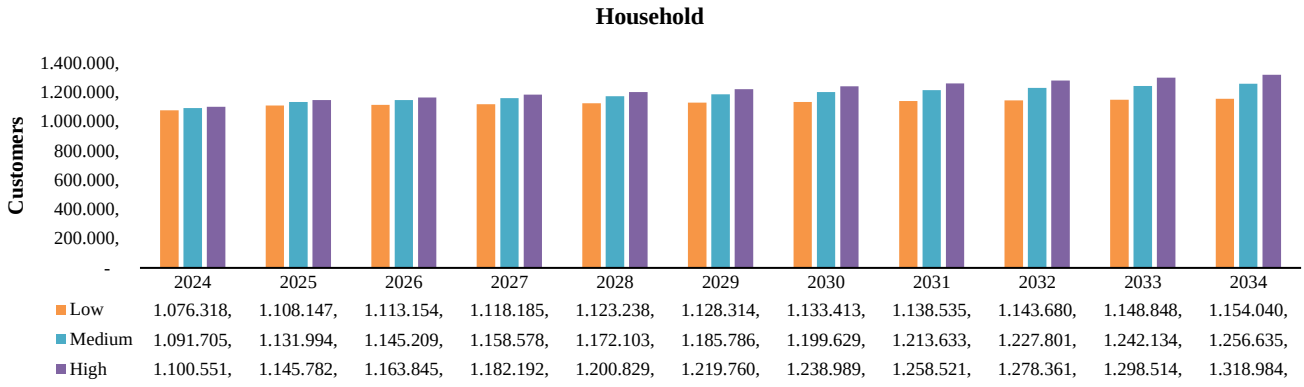


Fig 3. Forecast of the Number of Household Customers in High, Medium, and Low Scenarios for 2024-2034

C) Electricirty Demand

Based on Fig 4 below, the forecast results for NTT Province's electrical energy needs from the three scenarios continue to increase with the largest electrical energy demand still dominated by the household sector.

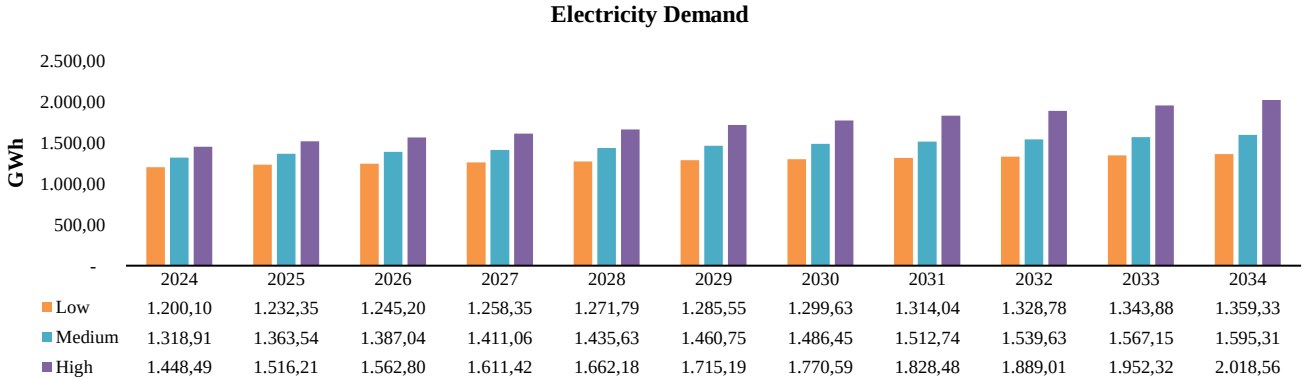
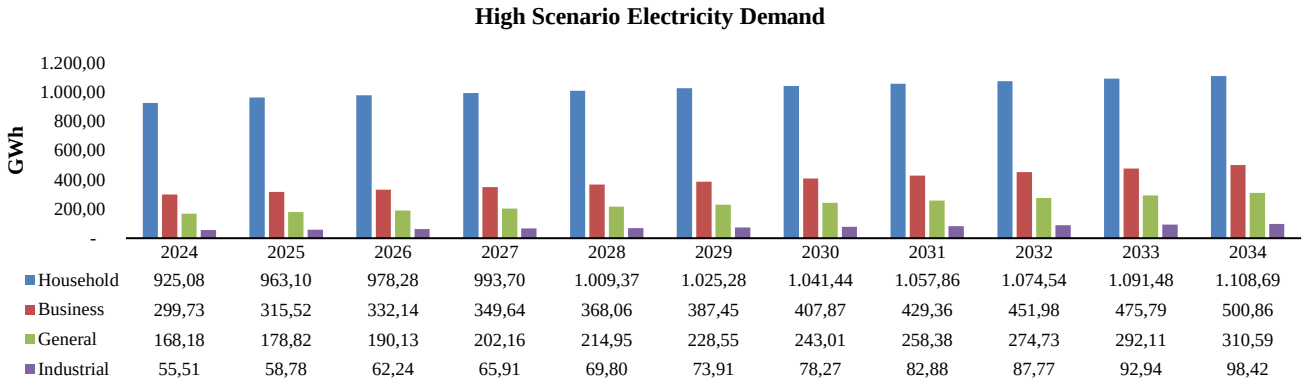


Fig 4. Electricity Demand Forecasting for High, Medium and Low Scenarios for 2024-2034

For the high scenario, the need for electrical energy in 2024 will be 1,448.49 GWh to 2,018.56 GWh in 2034 with an average growth of 3.50%. Then for electrical energy needs per sector, for the household sector, it is 1,108.69 GWh, followed by the business sector at 500.86 GWh, the general sector at 310.59 GWh, and the industrial sector at 98.42 GWh. With an average growth of 2.04% for the household sector, 5.27% for the business sector, 6.33% for the general sector, and 5.90% for the industrial sector.

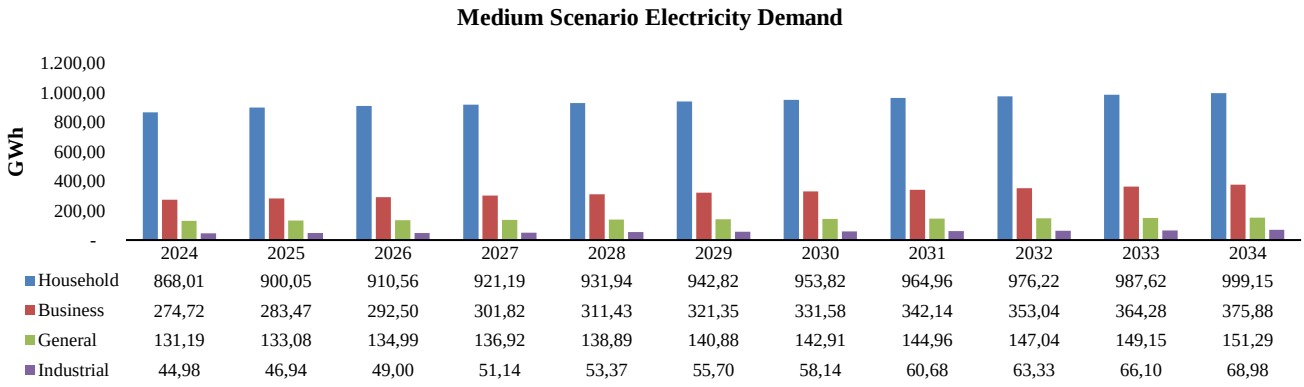
For the medium scenario, the need for electrical energy in 2024 will be 1,318.91 GWh to 1,595.31 GWh in 2034 with an average growth of 2.06%. Then for electrical energy needs per sector, for the household sector, it is 999.15 GWh, followed by the business sector at 375.88 GWh, the general sector at 151.29 GWh, and the industrial sector at 68.98 GWh. With an average growth of 1.63% for the household sector, 3.18% for the business sector, 1.44% for the general sector and 4.37% for the industrial sector.

For the low scenario, the need for electrical energy in 2024 will be 1,200.10 GWh to 1,359.33 GWh in 2034 with an average growth of 1.39%. Then for electrical energy needs per sector, for the household sector, it is 845.67 GWh, followed by the business sector at 364.08 GWh, the general sector at 120.72 GWh, and the industrial sector at 28.85 GWh. With an average growth of 0.91% for the household sector, 3.16% for the business sector, 0.39% for the general sector and 0.16% for the industrial sector. For more details, electrical energy requirements per customer sector for the three scenarios can be seen in Fig 4 (a), (b), and (c) below.



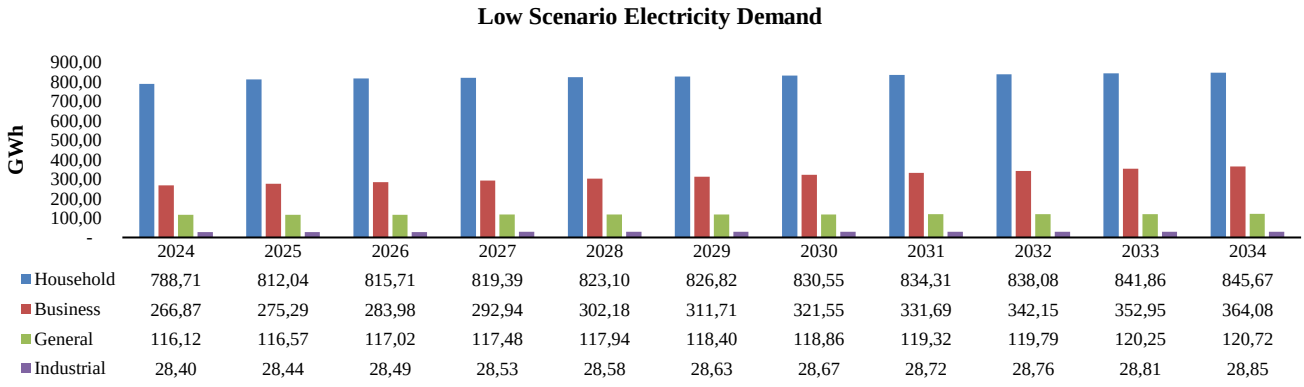
	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
Household	925,08	963,10	978,28	993,70	1.009,37	1.025,28	1.041,44	1.057,86	1.074,54	1.091,48	1.108,69
Business	299,73	315,52	332,14	349,64	368,06	387,45	407,87	429,36	451,98	475,79	500,86
General	168,18	178,82	190,13	202,16	214,95	228,55	243,01	258,38	274,73	292,11	310,59
Industrial	55,51	58,78	62,24	65,91	69,80	73,91	78,27	82,88	87,77	92,94	98,42

Fig 4. (a). High Scenario Electricity Demand Forecasting for 2024-2034



	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
Household	868,01	900,05	910,56	921,19	931,94	942,82	953,82	964,96	976,22	987,62	999,15
Business	274,72	283,47	292,50	301,82	311,43	321,35	331,58	342,14	353,04	364,28	375,88
General	131,19	133,08	134,99	136,92	138,89	140,88	142,91	144,96	147,04	149,15	151,29
Industrial	44,98	46,94	49,00	51,14	53,37	55,70	58,14	60,68	63,33	66,10	68,98

Fig 4. (b). Medium Scenario Electricity Demand Forecasting for 2024-2034



	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
Household	788,71	812,04	815,71	819,39	823,10	826,82	830,55	834,31	838,08	841,86	845,67
Business	266,87	275,29	283,98	292,94	302,18	311,71	321,55	331,69	342,15	352,95	364,08
General	116,12	116,57	117,02	117,48	117,94	118,40	118,86	119,32	119,79	120,25	120,72
Industrial	28,40	28,44	28,49	28,53	28,58	28,63	28,67	28,72	28,76	28,81	28,85

Fig 4. (b). Medium Scenario Electricity Demand Forecasting for 2024-2034

D) Installed Capacity of Power Plants

Based on the simulation results in Fig 5 below, the installed capacity of power plants for the three scenarios will increase and decrease. The purpose of the increase itself is that installed capacity needs to be added to meet electrical energy needs, while a decrease indicates that the installed capacity of power plants that use fossil energy (PLTU and PLTD) has experienced a decrease in installed capacity.

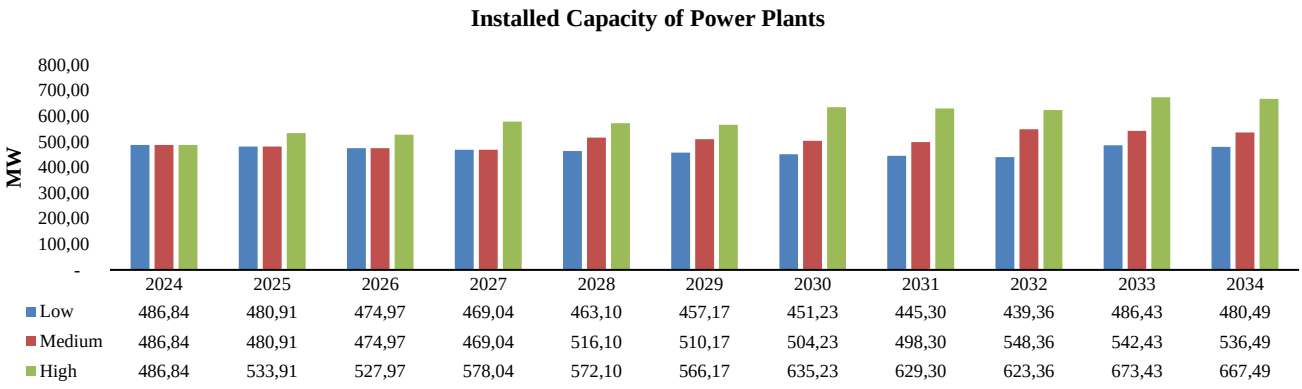


Fig 5. Forecasted Installed Capacity of Power Plants High, Medium, and Low Scenarios 2024-2034

For the high scenario, the installed capacity of power plants will increase in 2025, 2027, 2030, and 2033, with a total installed capacity of power plants at the end of 2034 amounting to 667.49 MW. For the medium scenario, the installed capacity of power plants will increase in 2028 and 2032, with a total installed capacity of power plants at the end of 2034 amounting to 536.49 MW. Meanwhile, for the low scenario, the installed capacity of power plants will increase in 2033, with a total installed capacity of power plants at the end of 2034 amounting to 480.49 MW. From the simulation results above, it was also found that the optimization of new renewable energy for the high, medium, and low scenarios can still be developed because, until 2034, NRE can still supply the demand for electrical energy per customer sector. More clearly, the forecast of installed capacity per type of power plant for the three scenarios can be seen in Figs 5 (a), (b), and (c) below.

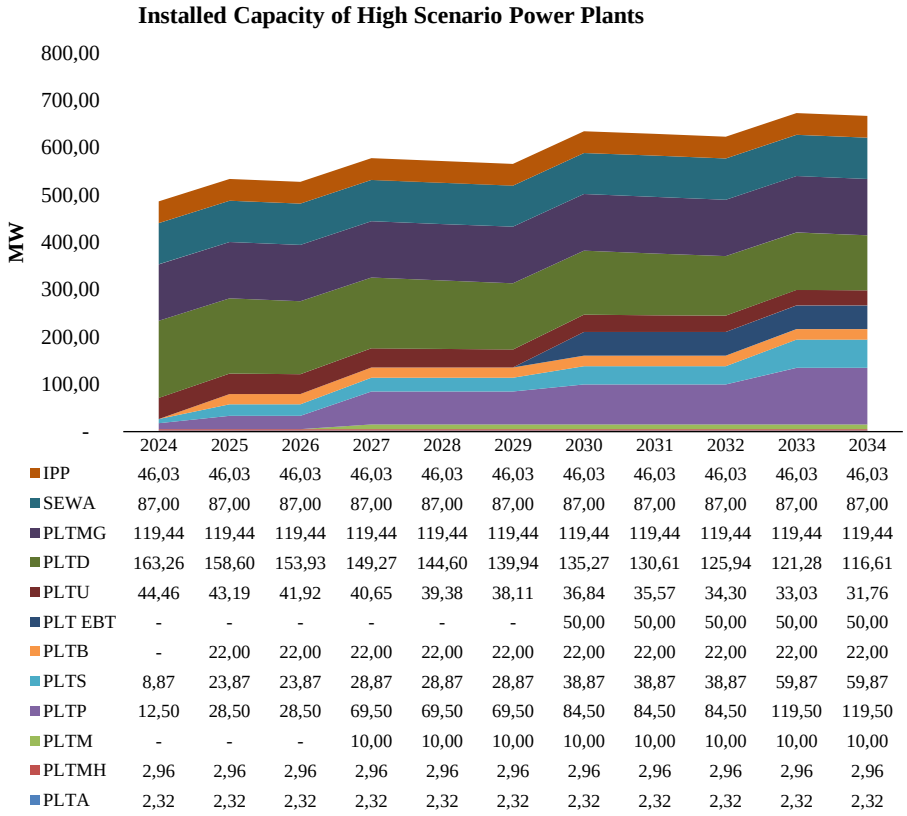
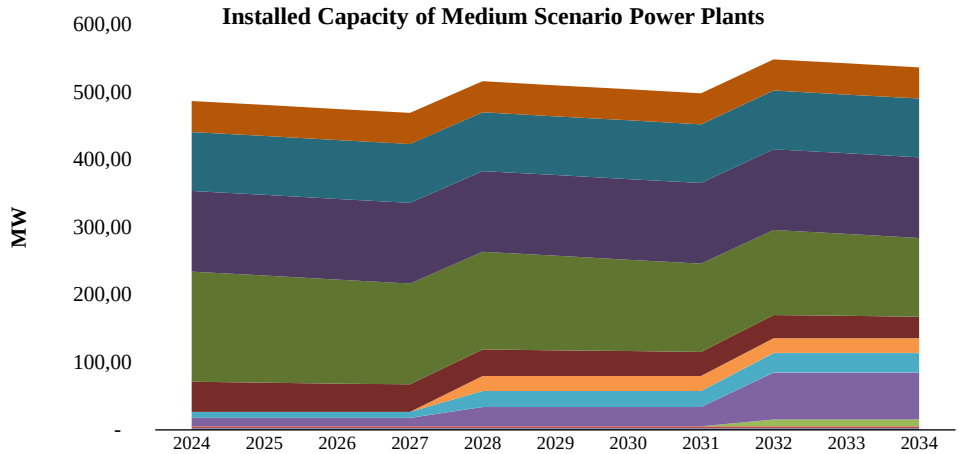
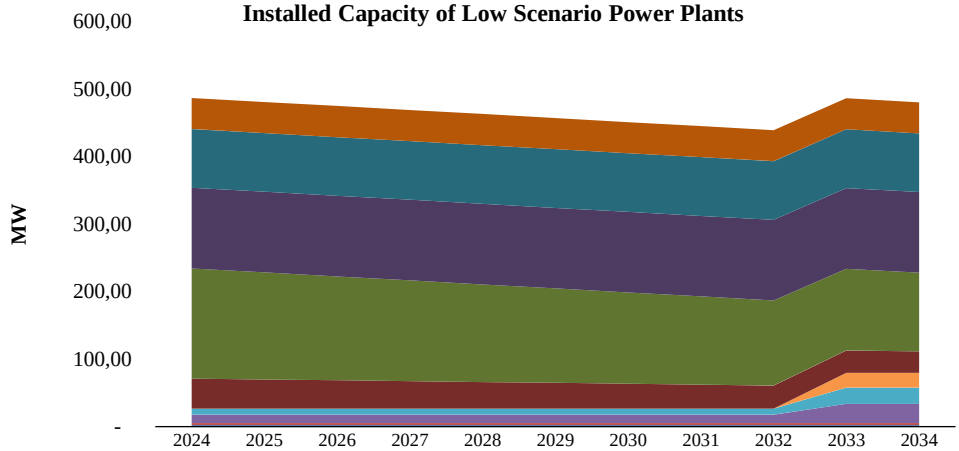


Fig 5. (a). Power Plant Capacity by Type, High Scenario 2024-2034



	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
IPP	46,03	46,03	46,03	46,03	46,03	46,03	46,03	46,03	46,03	46,03	46,03
SEWA	87,00	87,00	87,00	87,00	87,00	87,00	87,00	87,00	87,00	87,00	87,00
PLTMG	119,44	119,44	119,44	119,44	119,44	119,44	119,44	119,44	119,44	119,44	119,44
PLTD	163,26	158,60	153,93	149,27	144,60	139,94	135,27	130,61	125,94	121,28	116,61
PLTU	44,46	43,19	41,92	40,65	39,38	38,11	36,84	35,57	34,30	33,03	31,76
PLT EBT	-	-	-	-	-	-	-	-	-	-	-
PLTB	-	-	-	-	22,00	22,00	22,00	22,00	22,00	22,00	22,00
PLTS	8,87	8,87	8,87	8,87	23,87	23,87	23,87	23,87	28,87	28,87	28,87
PLTP	12,50	12,50	12,50	12,50	28,50	28,50	28,50	28,50	69,50	69,50	69,50
PLTM	-	-	-	-	-	-	-	-	10,00	10,00	10,00
PLTMH	2,96	2,96	2,96	2,96	2,96	2,96	2,96	2,96	2,96	2,96	2,96
PLTA	2,32	2,32	2,32	2,32	2,32	2,32	2,32	2,32	2,32	2,32	2,32

Fig 5. (b). Power Plant Capacity by Type, Medium Scenario 2024-2034



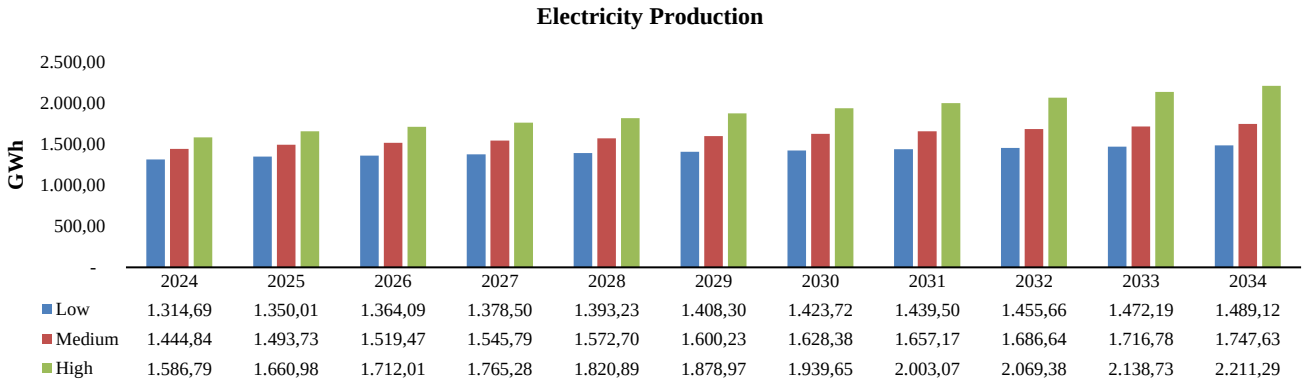
	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
IPP	46,03	46,03	46,03	46,03	46,03	46,03	46,03	46,03	46,03	46,03	46,03
SEWA	87,00	87,00	87,00	87,00	87,00	87,00	87,00	87,00	87,00	87,00	87,00
PLTMG	119,44	119,44	119,44	119,44	119,44	119,44	119,44	119,44	119,44	119,44	119,44
PLTD	163,26	158,60	153,93	149,27	144,60	139,94	135,27	130,61	125,94	121,28	116,61
PLTU	44,46	43,19	41,92	40,65	39,38	38,11	36,84	35,57	34,30	33,03	31,76
PLT EBT	-	-	-	-	-	-	-	-	-	-	-
PLTB	-	-	-	-	-	-	-	-	-	22,00	22,00
PLTS	8,87	8,87	8,87	8,87	8,87	8,87	8,87	8,87	8,87	23,87	23,87
PLTP	12,50	12,50	12,50	12,50	12,50	12,50	12,50	12,50	12,50	28,50	28,50
PLTM	-	-	-	-	-	-	-	-	-	-	-
PLTMH	2,96	2,96	2,96	2,96	2,96	2,96	2,96	2,96	2,96	2,96	2,96
PLTA	2,32	2,32	2,32	2,32	2,32	2,32	2,32	2,32	2,32	2,32	2,32

Fig 5. (c). Power Plant Capacity by Type, Low Scenario 2024-2034

E) Electricity Production

Based on the simulation depicted in Fig 6, it is apparent that the projected electrical energy output from each power plant for each scenario between 2024 and 2034 consistently demonstrates an upward trend. This escalation in electrical energy production is in tandem with the growing demand for electricity by consumers. It has been factored in each power plant's

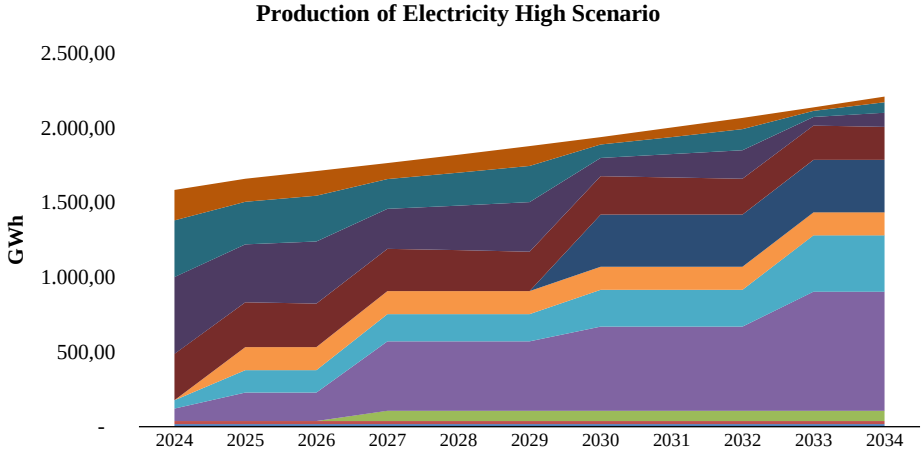
energy losses (transmission and distribution) and self-utilization.



	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
Low	1.314,69	1.350,01	1.364,09	1.378,50	1.393,23	1.408,30	1.423,72	1.439,50	1.455,66	1.472,19	1.489,12
Medium	1.444,84	1.493,73	1.519,47	1.545,79	1.572,70	1.600,23	1.628,38	1.657,17	1.686,64	1.716,78	1.747,63
High	1.586,79	1.660,98	1.712,01	1.765,28	1.820,89	1.878,97	1.939,65	2.003,07	2.069,38	2.138,73	2.211,29

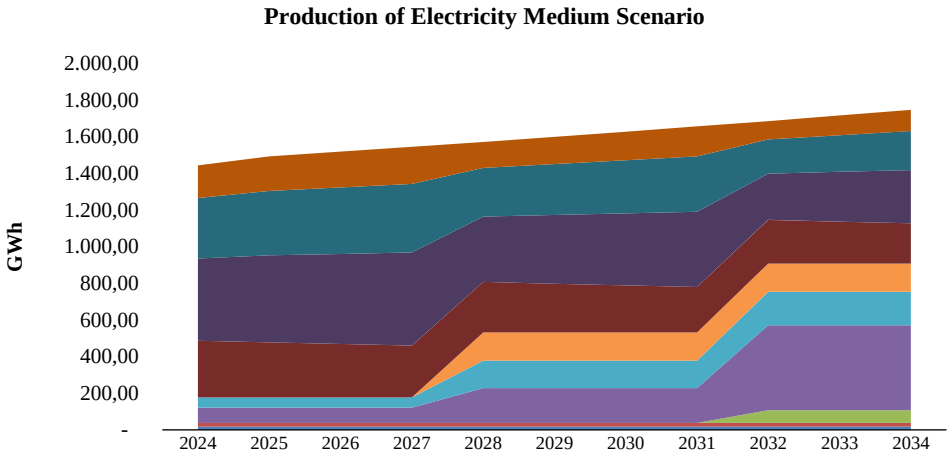
Fig 6. Projected Electricity Production Scenarios High, Medium, and Low for 2024-2034

For the high scenario, the electricity production in 2024 is 1,586.79 GWh, which will increase to 2,211.29 GWh in 2034. The power plant with the highest total production is the Geothermal Power Plant (PLTP), with a total production of 5,141.56 GWh until 2034. For the medium scenario, the electricity production in 2024 is 1,444.84 GWh, which increases to 1,747.63 GWh in 2034. The power plant with the highest total production is the Combined Gas Power Plant (PLTMG), with a total production of 4,273.75 GWh until 2034. Now, for the low scenario, the electricity production in 2024 is 1,314.69 GWh, which increases to 1,489.12 GWh in 2034. The power plant with the highest total production is also the Combined Gas Power Plant (PLTMG), with a total production of 4,637.66 GWh until 2034. For a clearer picture, the scenarios predicted electricity production per type of power plant for the three can be seen in Fig 6 (a), (b), and (c) below.



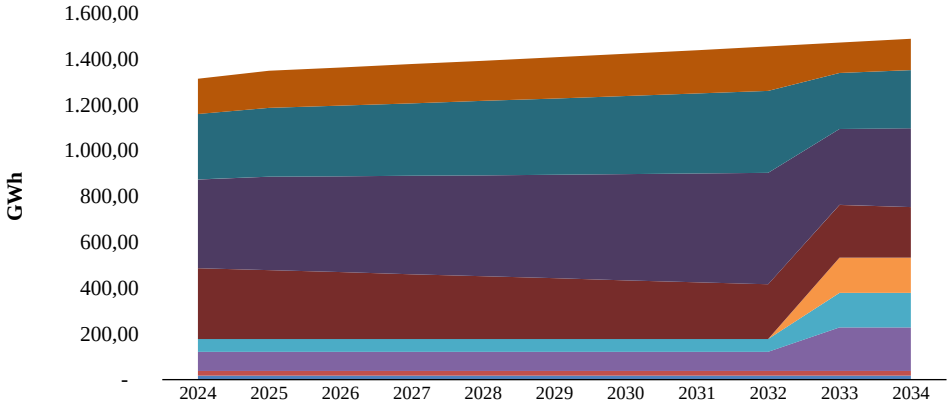
	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
IPP	204,94	154,14	165,30	107,07	119,09	131,56	48,80	62,27	76,28	22,62	37,80
SEWA	379,79	285,65	306,33	198,42	220,69	243,81	90,43	115,39	141,35	41,93	70,05
PLTMG	514,82	387,21	415,25	268,97	299,15	330,49	122,58	156,42	191,61	56,83	94,95
PLTD	-	-	-	-	-	-	-	-	-	-	-
PLTU	309,90	301,04	292,19	283,34	274,48	265,63	256,77	247,92	239,06	230,21	221,36
PLT EBT	-	-	-	-	-	-	350,40	350,40	350,40	350,40	350,40
PLTB	-	154,18	154,18	154,18	154,18	154,18	154,18	154,18	154,18	154,18	154,18
PLTS	55,97	150,62	150,62	182,17	182,17	182,17	245,27	245,27	245,27	377,78	377,78
PLTP	83,41	190,18	190,18	463,77	463,77	463,77	563,87	563,87	563,87	797,43	797,43
PLTM	-	-	-	69,40	69,40	69,40	69,40	69,40	69,40	69,40	69,40
PLTMH	20,54	20,54	20,54	20,54	20,54	20,54	20,54	20,54	20,54	20,54	20,54
PLTA	17,42	17,42	17,42	17,42	17,42	17,42	17,42	17,42	17,42	17,42	17,42

Fig 6. (a). Forecast of Electricity Production by Type of Power Plant High Scenario 2024-2034



	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
IPP	178,48	189,24	195,69	202,25	142,64	149,42	156,31	163,33	100,66	107,93	115,33
SEWA	330,76	350,70	362,65	374,80	264,33	276,90	289,68	302,68	186,55	200,02	213,73
PLTMG	448,35	475,39	491,59	508,06	358,31	375,34	392,67	410,30	252,87	271,13	289,72
PLTD	-	-	-	-	-	-	-	-	-	-	-
PLTU	309,90	301,04	292,19	283,34	274,48	265,63	256,77	247,92	239,06	230,21	221,36
PLT EBT	-	-	-	-	-	-	-	-	-	-	-
PLTB	-	-	-	-	154,18	154,18	154,18	154,18	154,18	154,18	154,18
PLTS	55,97	55,97	55,97	55,97	150,62	150,62	150,62	150,62	182,17	182,17	182,17
PLTP	83,41	83,41	83,41	83,41	190,18	190,18	190,18	190,18	463,77	463,77	463,77
PLTM	-	-	-	-	-	-	-	-	69,40	69,40	69,40
PLTMH	20,54	20,54	20,54	20,54	20,54	20,54	20,54	20,54	20,54	20,54	20,54
PLTA	17,42	17,42	17,42	17,42	17,42	17,42	17,42	17,42	17,42	17,42	17,42

Fig 6. (b). Forecast of Electricity Production by Type of Power Plant Medium Scenario 2024-2034



	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
IPP	154,22	162,46	166,73	171,07	175,46	179,92	184,45	189,04	193,70	132,15	136,96
SEWA	285,80	301,06	308,98	317,02	325,16	333,43	341,81	350,32	358,96	244,91	253,81
PLTMG	387,42	408,10	418,84	429,73	440,77	451,97	463,34	474,87	486,58	331,98	344,05
PLTD	-	-	-	-	-	-	-	-	-	-	-
PLTU	309,90	301,04	292,19	283,34	274,48	265,63	256,77	247,92	239,06	230,21	221,36
PLT EBT	-	-	-	-	-	-	-	-	-	-	-
PLTB	-	-	-	-	-	-	-	-	-	154,18	154,18
PLTS	55,97	55,97	55,97	55,97	55,97	55,97	55,97	55,97	55,97	150,62	150,62
PLTP	83,41	83,41	83,41	83,41	83,41	83,41	83,41	83,41	83,41	190,18	190,18
PLTM	-	-	-	-	-	-	-	-	-	-	-
PLTMH	20,54	20,54	20,54	20,54	20,54	20,54	20,54	20,54	20,54	20,54	20,54
PLTA	17,42	17,42	17,42	17,42	17,42	17,42	17,42	17,42	17,42	17,42	17,42

Fig 6. (c). Forecast of Electricity Production by Type of Power Plant Low Scenario 2024-2034

IV. CONCLUSION

Based on the research findings, it can be concluded that population growth and economic growth can increase the demand for electricity per customer sector (households, businesses, public, and industrial) in the NTT Province during the period 2024-2034.

For the High scenario, the total electricity demand rises from 1,448.49 GWh to 2,018.56 GWh with an average growth rate of 3.50%. In 2034, the household sector requires 1,108.69 GWh of electricity, businesses 500.86 GWh, public 310.59 GWh, and industry 98.42 GWh.

For the Medium scenario, the total electricity demand rises from 1,318.91 GWh to 1,595.31 GWh with an average growth rate of 2.06%. In 2034, the household sector requires 999.15 GWh of electricity, businesses 375.88 GWh, public 151.29 GWh, and industry 68.98 GWh.

Meanwhile, for the Low scenario, the total electricity demand rises from 1,200.10 GWh to 1,359.33 GWh with an average growth rate of 1.39%. In 2034, the household sector requires 845.67 GWh of electricity, businesses 364.08 GWh, public 120.72 GWh, and industry 28.85 GWh.

The optimization of NRE in all three scenarios (high, medium, and low) shows that NRE can supply the electricity demand until 2034. For the high scenario, NRE optimization is needed in 2025, 2027, 2030, and 2033, with the largest utilization from geothermal energy at 107 MW and the smallest from hydropower at 10 MW. Then, for the medium scenario, optimization is needed in 2028 and 2032, with the highest utilization of geothermal energy at 57 MW and the smallest of hydropower at 10 MW. As for the low scenario, NRE optimization is needed in 2033, with the highest utilization from wind energy at 22 MW and the smallest from solar energy at 15 MW.

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